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DISTINGUISHING THE SPECIES OF BRASSICA BY THEIR SEED

By

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NEED FOR IDENTIFICATION OF THE SEED

Until recent years this country depended almost entirely on foreign markets for its seed supply of *Brassica* for both planting and processing purposes. The imports in a representative prewar year (1934) averaged approximately 43½ million pounds of rape seed (winter rape and various oilseeds) and approximately 1½ million pounds of vegetable crops (cabbage, turnip, cauliflower, rutabaga, kale, kohlrabi). The disrupted trade conditions of the war years resulted in a great increase in domestic production. During the years 1942–45 this country produced annually approximately 40 million pounds of mustard seed (black, brown, and white), 6 million pounds of winter rape, and 4½ million pounds of the vegetable crops.[2]

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[1] Most of this work was done in the former Division of Seed Investigations, Bureau of Plant Industry. The writer wishes to express her gratitude to Edgar Brown, principal botanist in charge, of that Division, who made possible the extensive field and greenhouse studies in connection with this problem, and to the artist, Regina Olson Hughes, of the Division of Forage Crops and Diseases, for the degree of perfection attained on a difficult and exacting assignment. Further acknowledgment is made to Roland McKee, senior agronomist, Division of Forage Crops and Diseases, and to Joseph Ewan, associate botanist, Division of Plant Exploration and Introduction, for critical review of the manuscript.

While engaged in regulatory work under the Federal Seed Act in the former Division of Seed Investigations, the writer for eight successive years examined samples of all importations of *Brassica* seed drawn by Customs officials at the port of entry, as well as domestic samples. The laboratory examinations were followed by spring and fall plantings of each seed lot in the field for verification as to kind. Plantings were made about the middle of April and again about the middle of July. The field plantings averaged approximately 300 samples annually (exclusive of vegetable crops), the seed originating in China, India, Japan, continental Europe, Great Britain, and Argentina. Domestic seed production during this period was small and centered largely in California and the Pacific Northwest. During fall and winter months plantings were made in the greenhouse for observing distinguishing characters in the early seedling stages under the varying light conditions prevalent during the short-day seasons of the year.

Seeds of many of the kinds are very similar in appearance, so that they are not easily distinguished. Examination of hundreds of samples has shown that the name appearing on the label is not entirely dependable. This may be due to accidental misbranding or to the misapplication of a name as a result of local usage. For purposes of either planting or processing it is imperative therefore that the seed be readily and accurately recognized.

REVIEW OF LITERATURE

It was the belief of early systematists that the seeds are featureless and that no reliable differences exist between the species. Up to the turn of this century a number of investigations had been made on the histology of the seed coats, primarily to aid in identifying the composition of oilseed cakes used for stock feed. These and later histologic studies undeniably aid in clarifying plant relations, but the techniques involved prohibit the use of these methods for making such quick routine determinations as are needed by growers and seed law enforcement agencies. The morphology of the seed remains remarkably constant under varying environmental conditions of growth, yet this phase of the problem has been strangely neglected. Descriptions of seeds of *Brassica* in the literature are wholly inadequate, and seed illustrations seldom show any diagnostic features. The illustrations of Lund and Kjaerskou (*31*)[3] may be cited as an example. The finely executed drawings of seeds of *B. oleracea* and *B. campestris* do not show either the presence or character of surface stippling or differences in reticulations, both of which are important features in distinguishing these species.

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[2] Data supplied by the Bureau of Agricultural Economics, U. S. Department of Agriculture.

[3] The numbers in parentheses refer to Literature Cited, p. 33.

In describing the seedlings and fruits of cultivated species of *Brassica*, Percival (*41*, *42*) noted the size, shape, and color of the seeds, but recorded no observations on the character of the seed surface. It is stated that seeds of rape (*B. napus*) and Swede turnip (rutabaga) are identical and that charlock and turnip cannot be distinguished when mixed.

Roberts and Thomas (*46*) formulated a key for distinguishing the species on a combination of histological features of seed coats and such external features of the seed as size, shape, color, and surface configuration. No illustrations were given, and descriptions of the surface features are too general for specific application.

Winton and Moeller (*58*) and others observed that treatment with chloral hydrate solution changes the dark color of the palisade cells of charlock to a crimson red. Allen (*2*) obtained a red reaction by treating fragments of the seed coat of charlock with chloral hydrate, but found that this method is not entirely dependable if the seed is old, shriveled, or immature. Mohammed (*35*) distinguished seeds of *B. campestris* var. *sarson* from *B. juncea* and *B. napus* var. *dichotoma* by the prominent mucilaginous layer on the surface of sarson after being mounted in water for about an hour. Schwendiman (*59, pp. 36–37*) found that when seeds of rutabaga and wild turnip are treated with a 10-percent solution of hydrogen peroxide seeds of wild turnip give off oxygen bubbles more rapidly than those of rutabaga, provided the seeds are not immature or poorly developed or are not left in the solution longer than 3 minutes. Finlayson (*16*) found that by the use of polarized light upon the epidermal cells seeds of the cabbage group can be distinguished from rapes and mustards but that species and varieties in either group cannot be thus distinguished. Plitt (*44*) developed a method of making seed impressions on plastic film, thus showing an enlarged view of a seed surface. The success of the Finlayson and Plitt methods would also depend in large measure on the age and maturity of the seed and would require special equipment.

None of the treatments show any more diagnostic characters than can be obtained by simple visual examination. It is the purpose of this study to present graphically the distinguishing characters of the seeds as apparent from an examination of the seed surface under the comparatively low magnification of 40 to 60.

THE CLASSIFICATION OF *BRASSICA*

One of the major difficulties encountered in working with *Brassica* is the existing confusion in nomenclature. The vast accumulation of synonymy and citation indicates the variability of the plants and the indefiniteness of application of the early botanical names. It is often difficult to determine what plant is represented by a new arrangement of specific and varietal names or an old name. The use of vernacular names is equally misleading. These names often have only local application, and terms such as mustard or rape may represent totally different plants in the minds of different individuals.

A number of factors have doubtless contributed to this condition. Plants are susceptible of change under the influence of cultivation, soil, and climate, and new forms are developed by hybridization and selection. It is not unreasonable to conclude that throughout centuries of cultivation confusion in identity would arise. It is quite likely also that some confusion has resulted from the planting of seed from mislabeled packets or packets containing a mixture of kinds.

Herbarium material is often disappointing. The species of *Brassica* for the most part thrive in a cool humid climate, and their appearance may alter considerably under less favorable conditions. Many varieties are highly polymorphous, and different kinds may be strikingly similar at certain stages of their development, sometimes to the extent of being misleading in the preserved specimen. Certain species are distinctly dimorphous, as illustrated by the biennial turnip-rape. The familiar rosette of bright green, hispid, first-year leaves is succeeded the following spring by almost glabrous, lightly glaucous foliage scarcely distinguishable from the annual turnip-rape, commonly referred to in this country as bird rape. This variability, together with the size of the plants and the succulent nature of some of the kinds, makes it difficult to preserve in full character on the herbarium sheet the complete foliage, flower, mature fruit, and roots, all of which must be considered in making a critical study of the plant.

As already stated, the delimiting of species by the early botanists is conflicting and indefinite in many cases. To cite a few examples, Linnaeus (*29*) refers the rutabaga or Swede turnip to *B. oleracea*, winter rape to *B. napus*, turnip to *B. rapa*, and the common wild mustard, "weed colza," to *B. campestris*. Lamarck (*27*), using the bluish bloom and the pubescence of the leaves as a criterion, unites turnip and turnip-rape under *B. napus*, rape and rutabaga under *B. oleracea*. DeCandolle (*10, 11*) refers rutabaga, certain kales, and annual turnip-rape to *B. campestris*, winter rape to B. *napus*, and summer rape to *B. praecox*. DeCandolle's disposition of turnip and biennial turnip-rape is not clear. These plants are referred to *B. rapa*, with the contradictory description "basal leaves lyrate, glossy glaucous, devoid of setae." Metzger (*32*), using a series of definite characters as a basis, made a distribution of these forms that corresponds to the modern classification: Turnip and the turnip-rapes are referred to *B. rapa;* all forms of rape and rutabaga to *B. napus;* the coles to *B. oleracea*. The similar diagnoses of Lund and Kjaerskou (*30, 31*) were based on more detailed morphological characters, as well as anatomical features and chemical reactions, the specific name *campestris* being used instead of *rapa* for the turnip group. While it is probable that there can be no finality of opinion on the disposition of all forms in the genus, the more recent monographs are in general agreement on the major groups. Reference is made to the works of Hegi (*21*), Bailey (*5*), Schulz (*48*), Sinskaia (*51*), Lathouwers (*28*), Engler (*15*), and others.

Present-day investigators recognize the importance of the chromosome number as an aid in the determination of species. As pointed out by Sinskaia (*51*), however, crossability with other species and the character of the hybrids must also be taken into consideration in establishing the relationship of different forms. For example, *B. kaber* (*B. arvensis*) and *B. oleracea* have the same chromosome number, but no record has been found of a successful cross between the two species. Sutton (*54*) and others have shown that when a successful cross between distinct species is accomplished it may produce sterile hybrids or a segregation of nondescript character in F_2. Unfortunately, seed and plant specimens are rarely cited in the literature to substantiate the authenticity of materials used in cytological research. This is particularly important in the genus *Brassica*, since the seeds are not commonly recognized and the variable nature of the plants requires critical identification. In the absence of such records it can only be assumed that the reported results are based on authentic material.

The present report does not attempt to determine the priority of names in the much-involved nomenclature of the genus. Since type specimens are not available for examination, the classification here used is essentially as in the writer's previous publications [4] and is based on the relationships indicated by a critical study of the seed in relation to the living plant and the reported histological and cytological studies. Names used synonymously by systematists in several of the monographs consulted are included for reference.

SPECIES UNDER CONSIDERATION

This study includes species that are being grown in this country, imported for planting or other purposes, or occur spontaneously in fields and waste places. Introductions that appear on the market only sporadically are not considered. *Brassica adpressa* (Moench) Boiss. has been referred to *Hirschfeldia incana* (L.) Lagreze-Fossat and is not included in this study.

Taxonomically the species fall into three major divisions: (*a*) Rapes; (*b*) coles, or cabbage; and (*c*) mustards. Based on configuration of the seed surface, together with size, shape, and color, the species under consideration fall into three pattern groups that coincide with these three taxonomic divisions (table 1). Similar classifications have been proposed on the basis of chromosome number by Pearson (*40*), Howard (*23*), Crane (*13*), and others. The close correlation between seed character and the reported chromosomal complement of the plants also is shown in table 1.

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[4] MUSIL, A. F. THE IDENTIFICATION OF BRASSICAS FROM SEEDLING GROWTH. U. S. Dept. Agr. 5 pp., illus. 1941. [Processed.]

——— SEEDS OF COMMERCIAL SPECIES OF BRASSICA. U. S. Dept. Agr. 6 pp. illus. 1942. (Rev. 1945.) [Processed.]

TABLE 1.—*Species of Brassica grouped according to surface features of the seeds and their reported chromosomal complements*

Species and varieties	Common name	Chromosome No.		Authority for chromosome No.
		N	2N	
RAPES				
B. napus:				
var. *biennis*	Winter rape	19	38	Howard (*22*).
		19	----	Nagai and Sasaoka (*37*).
		19	----	U and Nagamatsu (*56*).
var. *annua*	Summer rape	19	----	Nagai and Sasaoka (*37*).
var. *napobrassica*	Rutabaga [1]	19	----	Do.
		19	38	Howard (*22*).
		19	38	U and Nagamatsu (*56*).
var. *pabularia*	Rape-kales:			
	Ragged Jack	19	----	Davey (*14*).
	Favourite kale	19	----	Nagai and Sasaoka (*37*).
	Fillgap kale	19	----	Davey (*14*).
	Siberian kale	----	----	
COLES, OR CABBAGES				
B. oleracea:				
var. *capitata*	Cabbage	9	----	Nagai and Sasaoka (*37*).
		9	----	U (*55*).
		9	----	Pearson (*40*).
		---	18	Karpetchenko (*24*).
var. *botrytis*	Cauliflower	---	18	Do.
		9	----	Nagai and Sasaoka (*37*).
Do	Broccoli	----	18	Karpetchenko (*24*).
var. *gongylodes*	Kohlrabi	9	----	Nagai and Sasaoka (*37*).
		---	18	Karpetchenko (*24*).
var. *gemmifera*	Brussels sprouts	9	----	Nagai and Sasaoka (*37*).
		---	18	Karpetchenko (*24*).
var. *acephala*	Collards	9	----	U (*55*).
Do	Leaf kales	9	----	Nagai and Sasaoka (*37*).
		9	----	Shimotomai (*49*).
Do	Thousand-headed kale.	----	18	Karpetchenko (*24*).
Do	Marrowfat kale	----	----	
var. *alboglabra*	Chinese kale	9	----	Pearson (*40*).
MUSTARDS				
B. campestris	Wild turnip	10	----	Shimotomai (*49*).
	Annual turnip-rape	10	----	U and Nagamatsu (*56*).
		---	20	Karpetchenko (*24*).
var. *autumnalis*	Biennial turnip-rape	----	20	Do.
var. *rapa*	Turnip	10	----	Shimotomai (*49*).
		10	----	Nagai and Sasaoka (*37*).
		---	20	Karpetchenko (*24*).
var. *sarson*	Sarson	----	20	Alam (*1*).
B. tournefortii	Wild turnip	----	----	
B. pekinensis	Petsai, or Chinese cabbage.	10	----	Shimotomai (*49*).
		10	----	Nagai and Sasaoka (*37*).

TABLE 1.—*Species of Brassica grouped according to surface features of the seeds and their reported chromosomal complements*—Continued

Species and varieties	Common name	Chromosome No.		Authority for chromosome No.
		N	2N	
MUSTARDS—Con.				
B. chinensis	Pakchoi, or white celery mustard.	10	----	Nagai and Sasaoka (*37*).
		10	----	U and Nagamatsu (*56*).
B. perviridis	Spinach mustard, or Tendergreen.	10	20	Karpetchenko (*24*).
B. nigra	Black mustard	8	----	Nagai and Sasaoka (*37*).
		8	----	U (*55*).
		---	16	Karpetchenko (*24*).
B. hirta (*B. alba*)	White mustard	12	----	Nagai and Sasaoka (*37*).
		---	24	Karpetchenko (*24*).
B. juncea	Brown, or India, mustard, including Fordhook Fancy and Southern Giant Curled.	18	----	Nagai and Sasaoka (*37*).
		18	----	U (*55*).
		18	----	Shimotomai (*49*).
		---	36	Alam (*1*).
		---	36	Karpetchenko (*24*).
B. kaber (*B. arvensis*)	Charlock	9	----	Nagai and Sasaoka (*37*).
		---	18	Karpetchenko (*24*).

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[1] Howard (*22*) has shown that the number $N=18$, previously reported for rutabaga, appears to be incorrect.

RAPE

Brassica napus L.

The species *Brassica napus* is characterized by foliage that is glaucous, glabrous, or sparingly setose; the inflorescence an elongating raceme, the flowers large and aggregated at the top but not prominently overtopping the terminal buds, often with open flowers along the axis below; calyx more or less open; sepals not appressed or saccate. The early systematists described the species as completely devoid of hairs on the leaves. It has been shown by Calder and Doak (*9*) that setae occur on the leaves of certain types of New Zealand winter rape. The present writer has observed that some pubescence may be present, especially on young leaves, in certain strains of all varieties of the group.

The rapes, including both annual and biennial forms, are utilized for forage, oil, and as greens for table use. The species *napus* is represented in this country by four distinct varieties: (*a*) Winter rape, (*b*) summer rape, (*c*) rutabaga, and (*d*) rape-kale. Ascherson and Graebner (*4*) have been followed in the taxonomy of this species.

WINTER RAPE; SWEDE RAPE

Brassica napus var. *biennis* (Schubl. and Mart.) Reichb. (*4, p. 29*)

Ger., Winterraps; Fr., Colza d'hiver; Dutch,[5] Winterkoolzaad; Sp., Rape [6]

DeCandolle (*10, p. 592*)	*B. napus* A *oleifera*
Metzger (*32, p. 40*)	*B. napus oleifera biennis*
Hegi (*21, p. 254*)	*B. napus* var. *arvensis* (Lam.) Thell. f. *biennis* (Schubl. and Mart.) Thell.
Schulz (*48, p. 44*)	*B. napus* var. *biennis* (Schubl. and Mart.) Reichb.
Bailey (*5, p. 81*)	*B. napus* L.
Sinskaia (*51, p. 245*)	*B. napus oleifera* Metzg.
Engler (*15, p. 218*)	*B. napus* var. *oleifera* DC.

Winter rape, a biennial or winter annual, is widely planted for fall and winter pasture in cool and humid regions (fig. 1). There are a number of recognized agronomic varieties or strains, but in this country the variety Dwarf Essex is planted almost exclusively, so that the varietal name is sometimes used synonymously for winter rape. The source of imported seed is chiefly central and western Europe, Great Britain, and Japan. According to Amos (*3*), Bayona (*8*), and Zinny (*60*), winter rape is grown in Argentina, but no importations have been received from that source. Domestic production is largely confined to the more humid areas of the Pacific Northwest.

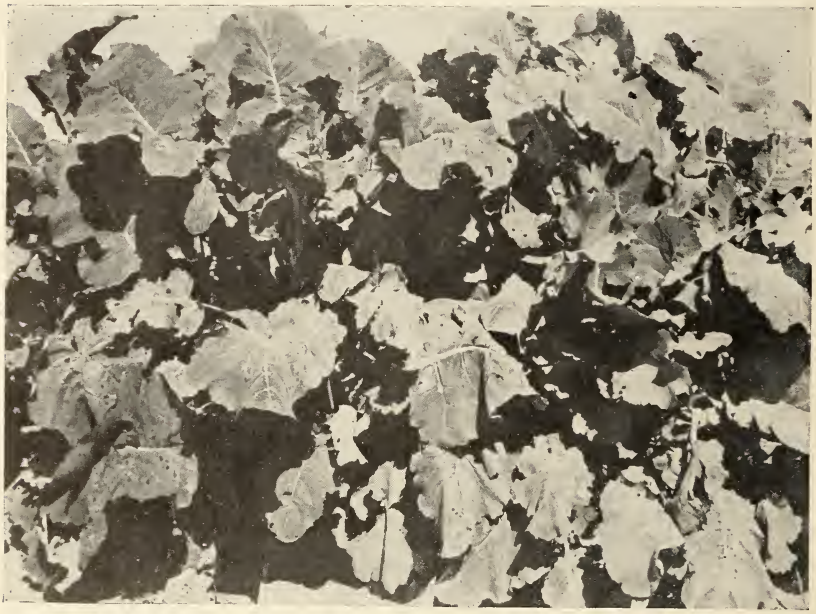

Figure 1.—Winter rape (*Brassica napus* var. *biennis* (Schubl. and Mart.) Reichb.). Photographed 10 weeks after planting.

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[5] Dutch common names according to Franck (*17*).

[6] According to Amos (*3*) there is no Spanish name for winter rape.

SUMMER RAPE

Brassica napus var. *annua* Koch (*4, p. 26*)

Ger., Sommerraps; Fr., Colza de Printemps; Dutch, Zommerkoolzaad; Sp., Colza

DeCandolle (*10, p. 593*)	*B. praecox* Waldst. and Kit.
Metzger (*32, p. 45*)	*B. napus oleifera annua*
Hegi (*21, p. 254*)	*B. napus* var. *arvensis* (Lam.) Thell. f. *annua* (Schubl. and Mart.) Thell.
Schulz (*48, p. 42*)	*B. napus* em. f. *typica* Pospichal
Sinskaia (*51, p. 245*)	*B. napus oleifera*
Engler (*15, p. 218*)	*B. napus* var. *annua* Koch

As the name implies, summer rape is an annual (fig. 2). It is essentially an oilseed plant and does not produce the abundant leafage of winter rape. When planted in spring it runs into flower quickly and then dies down. When planted in fall in the latitude of Maryland the plants do not flower, and in this phase the planting appears very similar to that of winter rape.

Summer rape is grown extensively as an oilseed crop in central and western Europe and to some extent in South America. Records of the past 30 years show that the seed has not been imported for either planting or processing, but it has been offered to the trade as a substitute for winter rape in times of scarcity of seed of the latter.

RUTABAGA; SWEDE TURNIP

Brassica napus var. *napobrassica* (L.) Reichb. (*4, p. 30*)

Ger., Kohlrübe; Fr., Chou-navet; Dutch, Koolraap; Sp., Colinabo

DeCandolle (*10, p. 589*)	*B. campestris* C *napo-brassica*
Metzger (*32, p. 46*)	*B. napus* var. *rapifera*
Hegi (*21, p. 255*)	*B. napus* var. *napobrassica* (L.) Peterm.[7]
Schulz (*48, p. 44*)	*B. napus* var. *napobrassica* (L.) Reichb.
Bailey (*5, p. 81*)	*B. napobrassica* (L.) Mill.
Sinskaia (*51, p. 262*)	*B. napus* subsp. *rapifera* Metzg.
Engler (*15, p. 218*)	*B. napus* var. *napobrassica* (L.) Reichb.

Bailey (*5, pp. 81–83*) accords rutabaga specific rank, stating that its affinity is clearly with *B. napus* and that distinctions between them are close, but for descriptive purposes it is preferable to keep them separate, and this disposition is followed by the Division of Plant Exploration and Introduction. The character of stem leaves and pods is admittedly variable, however, and not always distinct from *B. napus*. The size and surface features of the seed place it unmistakably in the *napus* group. The plant bears the same chromosome number as *B. napus* (table 1, p. 6) and crosses readily with it, as reported by Davey (*14*), the National Institute of Agricultural Botany, at Cambridge (*38*), and others. These facts would indicate that rutabaga is a variety of *B. napus* and not a distinct species.

Rutabaga is grown extensively throughout the country, the enlarged tubers being utilized both for table use and stock feed and the young tops for greens. There are several horticultural varieties of the species in cultivation.

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[7] The cited author of the variety is apparently an error and should be (L.) Reichb.

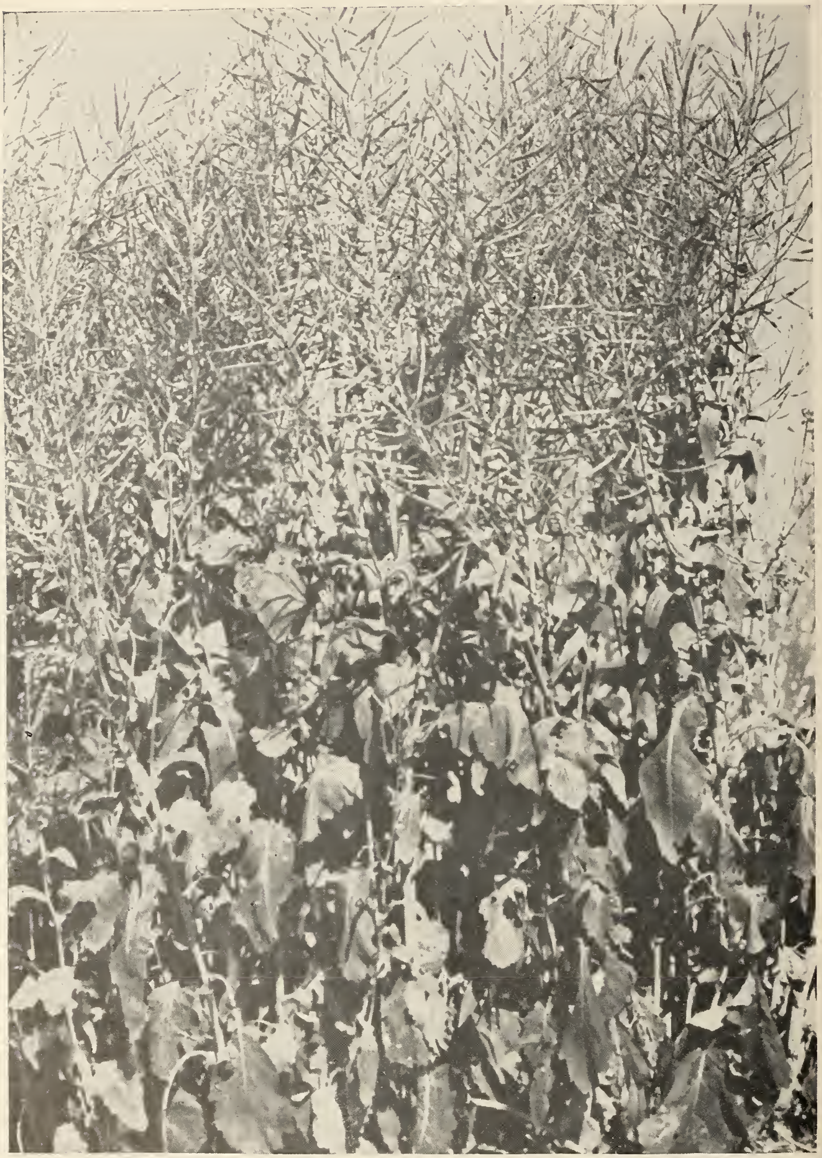

Figure 2.—Summer rape (*Brassica napus* var. *annua* Koch). Photographed 10 weeks after planting.

RAPE-KALE

Brassica napus var. *pabularia* (DC.) Reichb. (*4, p. 29*)

Ger., Schnittkohl; Fr., Chou à faucher; Dutch, Snijkool

DeCandolle (*10, p. 589*)	*B. campestris* B *pabularia*
Metzger (*32, p. 44*)	*B. campestris pabularia*
Hegi (*21, p. 255*)	*B. napus arvensis* (Lam.) Thell. f. *biennis* (Schubl. and Mart.) Thell. subf. *pabularia* (DC.) Thell.
Schulz (*48, p. 44*)	*B. napus* var. *pabularia* (DC.) Reichb.
Bailey (*7, p. 324*)	*B. fimbriata* (Mill.) DC.
Sinskaia (*51, p. 249*)	*B. napus oleifera* var. *pabularia* (DC.) Reichb.

Rape-kales are grown rather widely for fodder in European countries under such names as Asparagus kale, Ragged Jack kale, and others, according to Giles (*19*). The group is represented in this country by only one variety, Siberian kale, which is grown chiefly for table use as greens.

Bailey (*7*) refers Siberian kale to the same species as the curled kitchen kales and Scotch kale (*Brassica fimbriata*), citing as a synonym Miller's (*33*) *B. oleracea* var. *fimbriata*, "Siberian borecole, called by some Scotch kale." It is not clear whether the Siberian borecole referred to by Miller is the same plant as the one under consideration. Herbarium seed samples of the various kales have been reexamined, particularly United States Department of Agriculture No. 224222, cited by Bailey as one source of his plant material of Siberian kale. The seed of Siberian kale is quite distinct from the curled kitchen kales and Scotch kale. As will be shown later, seed of Siberian kale shows a close relationship to the rape-kales of the *napus* group, those of the kitchen kales to the *oleracea* group. Cytologically, the two groups also are distinct, the haploid chromosome number of the leaf kales being 9, that of the rape-kales 19 (table 1, p. 6). No record was found in the literature of the chromosome number of Siberian kale. More cytological work on these plants would doubtless aid in clarifying their relationship.

COLE; CABBAGE

Brassica oleracea L.

Heading cabbage, *B. oleracea* var. *capitata* L. (*5, p. 78*)
Collards, *B. oleracea* var. *acephala* DC. (*5, p. 76*)
Kale, *B. oleracea* var. *acephala* DC. (*5, p. 74*)
Cauliflower and broccoli, *B. oleracea* var. *botrytis* L. (*5, p. 79*)
Brussels sprouts, *B. oleracea* var. *gemmifera* Zenker (*5, p. 77*)
Kohlrabi, *B. oleracea* var. *gongylodes* L. (*5, p. 79*)

There is general agreement that the heading and nonheading cabbages, kales, cauliflower, broccoli, brussels sprouts, and kohlrabi are the same species, assuming that the forms are all derived from the wild *Brassica oleracea* of the coastal regions of Europe. With the exception of some of the kitchen kales, the cultivated forms of the *oleracea* group are characterized by thick and somewhat leathery, glaucous glabrous foliage; inflorescence in long racemes, the large opened flowers along the axis below the terminal buds; calyx narrow and erect; sepals appressed to the corolla and somewhat saccate at the base. There are many recognized botanical and horticultural varieties in the species, but only the more important botanical varieties are considered here, the classification of Bailey being followed for these varieties. Seeds of these varieties are very similar, and a seedling test is often necessary for positive determination.

Some authors, including Bailey (*7, p. 324*), refer the curled kitchen kales to *B. fimbriata* (Mill.) DC., and it is possible that future investigation may justify such a disposition. There are several varieties of forage kales in the *oleracea* group, but only two are being grown in this country, thousand-headed and marrowfat. The latter is of only minor importance.

Chinese kale, *B. oleracea* var. *alboglabra* (Bailey) Musil, comb. nov., based on *B. alboglabra* Bailey (*5, p. 79, fig. 29*), is an annual with typical inflorescence of *B. oleracea.* The character of the seed, the reported chromosome number (table 1), and crossability with varieties of *B. oleracea* (Sinskaia (*50, p. 162*)) indicate that this is a variety of *B. oleracea* and not a distinct species. The crop is of relatively minor importance.

Mustard

The mustards, involving several species, include a wide variety of plants, the relationship of which is not always readily apparent. The foliage varies with the kind, from bright green and hispid to lightly glaucous and glabrous. Flowers are small, clustered at the top of the raceme, usually overtopping the terminal buds; sepals exceeding claws of petals and somewhat spreading. The plants have a wide variety of uses, as greens for table use, condiments, oil, stock feed, cover crops, and feed for cage birds. Certain of the species are of economic interest because of their noxious character as field weeds.

The plants in this heterogeneous group segregate into five rather distinct classes: (*a*) Turnip and allies, including certain oriental or Chinese mustards; (*b*) black mustard; (*c*) white mustard; (*d*) brown or India mustard; and (*e*) charlock. The taxonomy of Ascherson and Graebner (*4*) has been followed in the classification of turnip and allies, except the oriental mustards. The classification of Bailey (*5, 7*) has been adopted for the oriental, black, and brown mustards, and that of Wheeler (*57*) for white mustard and charlock.

The taxonomic position of the oriental mustards is none too clear. They are considered by some authors as varieties of *Brassica napus*, by others as varieties of *B. campestris.* The character of the seed and the reported chromosome number of the kinds under consideration indicate a close relationship to the *B. campestris* group (table 1, p. 6). Sinskaia (*51*) points out that while *B. chinensis* and *B. pekinensis* cross readily with *B. campestris* and less freely with *B. napus*, the character of the segregation in F_2 makes it clear that they should not be regarded as varieties of either *B. napus* or *B. campestris*. Sun (*52*), in his evaluation of taxonomic characters of cultivated *Brassica,* suggests dividing the 10-chromosome group into two geographic races, one oriental and the other western. The oriental, including *B. chinensis* and *B. pekinensis*, to be known as *B. chinensis*, and the western race, including turnip and turnip-rape, by the old name *B. campestris.*

The turnip-rapes are not cultivated here, but large importations of these seeds have been received for processing in past years. Because the plants are so little known, the relationship of the annual and biennial forms has not been generally recognized in this country, the biennial form being commonly designated as turnip-rape (*B. rapa* var.) and the annual form as bird rape (*B. campestris*). Lacking an English equivalent for the German "Rübsen" and the French "Navette," the terms "annual turnip-rape" and "biennial turnip-rape" are proposed as common names for these two varieties.

Charlock and the black, white, and brown mustards are readily distinguished from turnip and its allies by the nonclasping stem leaves and characteristic pods. For this reason they are referred by some authors to the genus *Sinapis*. Seeds of black, white, and brown mustard, according to Goss (*20*) and Parker (*39*), are used for planting as cover crops, for oil extraction, and in the preparation of table mustard. Domestic seed production is confined chiefly to California, Montana, Washington, Oregon, and North Dakota, where they are grown as field crops or obtained as a byproduct from grain. The species are all quick-growing annuals, and because of their profuse seeding habits they often become undesirable field weeds.

TURNIP AND ALLIES

Five classes comprise this group of mustards: (*a*) The so-called wild turnips; (*b*) turnip-rape, annual and biennial forms; (*c*) edible turnip; (*d*) sarson; and (*e*) oriental vegetable mustards.

Opinions among botanists differ as to the application of the specific names *campestris* and *rapa* to plants in the turnip and turnip-rape groups, and the two names are often considered synonymous.[8] Some authors separate *Brassica rapa* from *B. campestris* on the basis of a rosette of lyrate, hispid crown leaves and enlarged tuberous base, but flowers and fruit are described as in *B. campestris*. An analogous condition exists in the dimorphous habit of biennial turnip-rape, yet it is generally agreed that the annual and biennial forms of turnip-rape are but varieties of *B. campestris*. Bailey (*5, p. 85*) points out that seeds of *B. rapa* are larger than those of *B. campestris*. It will be shown (figs. 7 and 8) that size of seed cannot be considered a criterion in distinguishing the two species. The species *rapa* as delimited above would exclude the Shogoin, or foliage, turnips with glabrous strap-shaped leaves and the seventop turnip with many stems arising from a woody taproot. Moreover, turnips often persist as escapes from cultivation, and these spontaneous plants of fields and waste places are classified as *B. campestris*, regardless of the fact that their immediate ancestors were classified as *B. rapa*. Because of the variable nature of these plants it is difficult to draw a clear line of distinction between the species *B. rapa* and *B. campestris*, and it would appear logical to consider them all as varieties of either one or the other of the two species. The writer has, therefore, adopted the classification based on the older name *B. campestris*. This is in agreement with the recent monograph on cultivated *Brassica* by Sun (*52, 53*).

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[8] *B. rapa* is used by the Division of Plant Exploration and Introduction for the edible turnip and biennial turnip-rape, and *B. campestris* for wild turnip and annual turnip-rape.

Wild Turnip

Brassica tournefortii Gouan. (*4, p. 45*)

A native of the Mediterranean region, the wild turnip is known to be established locally in the Coachella Valley of southern California. It is reported to be a troublesome weed of grainfields in certain countries. The plant (fig. 3) and its behavior as a field weed in Australia are described by Gardner and Throssell (*18*) and Clarke (*12*).

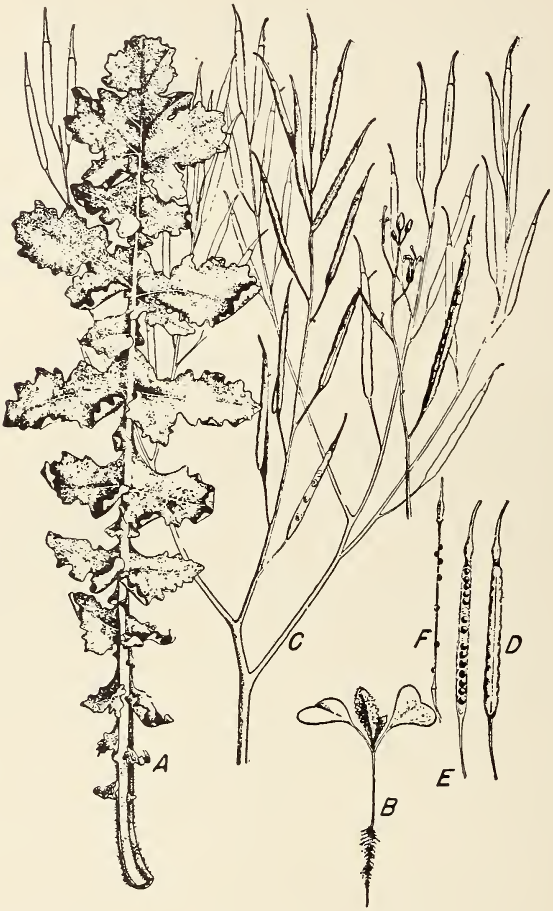

Figure 3.—Wild turnip (*Brassica tournefortii* Gouan.): *A*, Leaf (one-third natural size); *B*, young plant, showing primary and secondary leaves; *C*, branch of fruiting stalk; *D*, silique, showing dorsal nerve of one valve and seed in beak; *E*, silique with one valve removed; *F*, silique with both valves removed, showing the persistent beak and some seeds attached to the central partition. (After Gardner (*18*).)

Brassica campestris L. (*4, p. 31*)

Hegi (*21, p. 260*)	*B. rapa* var. *silvestris* (Lam.) Purchas and Ley f. *campestris* (L.) Bogenhard
Schulz (*48, p. 45*)	*B. campestris* L.
Bailey (*5, p. 84*)	*B. campestris* L.

Many authors refer the widely distributed wild mustard, charlock excluded, to *Brassica campestris*, while others make no distinction between the wild and cultivated annual forms (DeCandolle (*10, p. 588*), Metzger (*32, p. 49*), and others), referring both to the same variety as either *B. campestris* or *B. rapa*.

According to Bailey (*5*) there are no indigenous species of *Brassica* in this country. Seed of the cultivated annual form is imported for processing, but it has not been grown as a crop here, and its possible introduction as an extraneous seed in other imported field seeds is rather remote. In the western part of this country, particularly on the Pacific coast, where it occurs quite abundantly in some areas, the plant behaves as a winter annual, producing in fall a rosette of bright-green hispid leaves with a thickened woody taproot and flowering the following spring. Similar plants are sometimes found in clover fields in the Southeast, where it is known to have been the practice in some localities to plant turnip seed with the clover seed. All the available evidence indicates that these so-called wild turnips are degenerate or run-wild forms of garden turnip. The seed is sometimes screened in quantity out of grain. Fall plantings of such screenings made in the vicinity of Washington, D. C., produced mostly biennial plants, with a few of the annual type present. It was not determined whether this was the result of natural segregation or whether the seed planted was a mixture of annual and biennial types.

Annual Turnip-rape

Brassica campestris L. (*4, p. 31*)

Ger., Sommerrübsen; Fr., Navette d'été; Dutch, Zommerraapzaad; Sp., Nabo de verano

DeCandolle (*10, p. 588*)	*B. campestris* A *oleifera*
Metzger (*32, p. 51*)	*B. rapa oleifera annua*
Hegi (*21, p. 260*)	*B. rapa* L. var. *silvestris* (Lam.) Purchas and Ley f. *annua* (Metzg.) Koch
Schulz (*48, p. 46*)	*B. campestris* L.
Sinskaia (*51, p. 65*)	*B. campestris* L.
Engler (*15, p. 218*)	*B. campestris* var. *annua* Reichb.

This cultivated form is similar to the wild *Brassica campestris* but is usually more robust in growth habit (fig. 4). There are numerous recognized varieties and strains in cultivation, especially in the Orient, where annual forms are grown extensively. Except for some experimental plantings the crop is not grown commercially in this country, the seed being imported for processing from Argentina, Europe, and India.

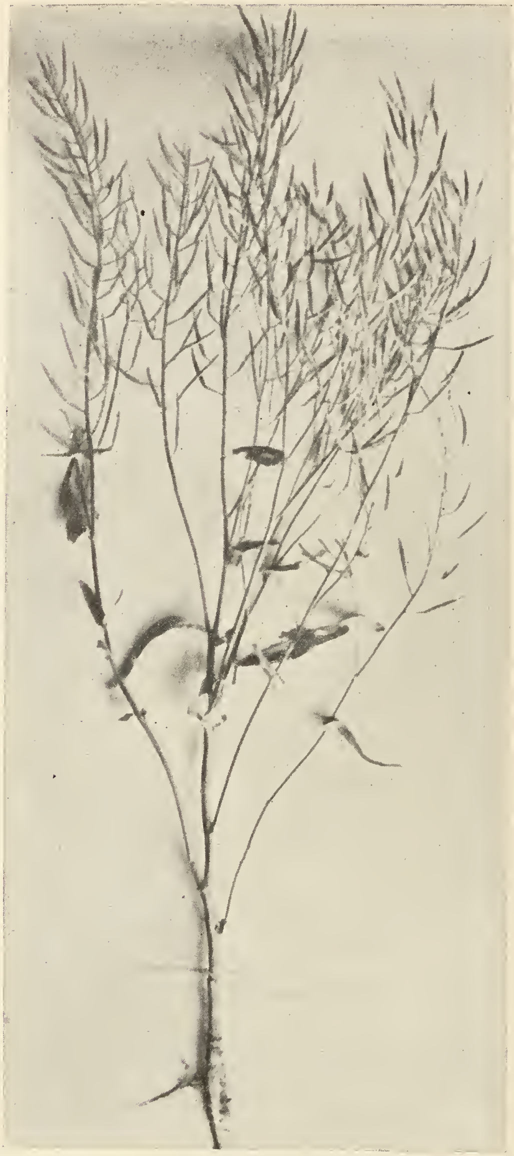

FIGURE 4.—Annual turnip-rape (*Brassica campestris* L.). Photographed 10 weeks after planting.

BIENNIAL TURNIP-RAPE

Brassica campestris var. *autumnalis* DC. (*4, p. 34*)

Ger., WINTERRÜBSEN; Fr., NAVETTE D'HIVER; Dutch, WINTERRAAPZAAD; Sp., NABO DE INVIERNO

DeCandolle (*10, p. 591*)	*B. rapa* C *oleifera*
Metzger (*32, p. 50*)	*B. rapa oleifera biennis*
Hegi (*21, p. 261*)	*B. rapa* var. *silvestris* (Lam.) Purchas and Ley f. *biennis* (Metzg.) Alef.
Schulz (*48, p. 49*)	*B. campestris* var. *autumnalis* DC.
Sinskaia (*51, p. 83*)	*B. campestris* var. *autumnalis* DC.
Engler (*15, p. 218*)	*B. campestris* var. *oleifera*

In its first year of growth biennial turnip-rape resembles garden turnip, with its rosette of hispid, bright green lyrate leaves, but lacks the swollen tuber at the base (fig. 5). The following spring

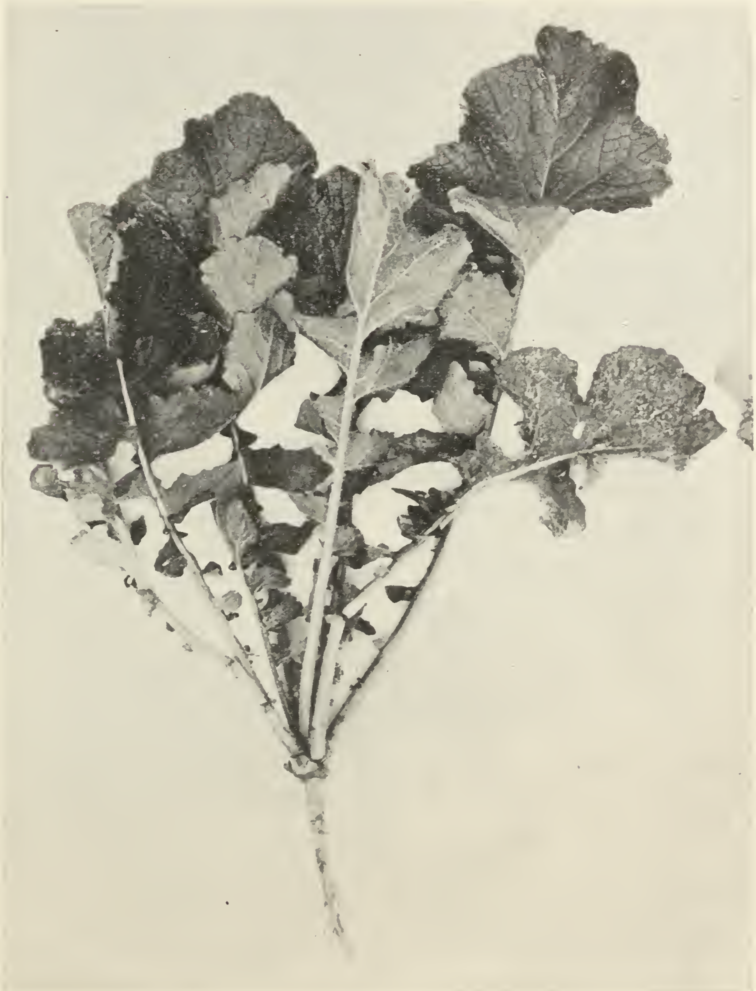

FIGURE 5.—Biennial turnip-rape (*Brassica campestris* var. *autumnalis* DC.). Photographed 10 weeks after planting.

the plant sends up a flowering stalk with smooth, almost glabrous, lightly glaucous stem leaves. At this stage the plant is scarcely distinguishable from the annual form, shown in figure 4. Biennial turnip-rape is not a cultivated crop in this country. The seed is imported for oil and bird feed, chiefly from central and western Europe.

TURNIP

Brassica campestris var. *rapa* (L.) Hartm. (*4, p. 34*)

Ger., RÜBE; Fr., NAVET; Dutch, KOOLRAAP; Sp., NABO

DeCandolle (*10, p. 590*)	*B. rapa* A *depressa*
Metzger (*32, p. 52*)	*B. rapa rapifera*
Hegi (*21, p. 261*)	*B. rapa* var. *rapa* (L.) Thell.
Schulz (*48, p. 49*)	*B. campestris* var. *rapa* (L.) Hartm.
Bailey (*5, p. 85*)	*B. rapa* L.
Sinskaia (*51, p. 103*)	*B. campestris* var. *rapifera* Metzg.
Engler (*15, p. 218*)	*B. campestris* var. *rapifera* Metzg.

Turnip is characterized by a swollen tuberous base and bright-green, hispid, lyrate crown leaves. According to Bailey (*6*) the species includes two botanical varieties: The variety *lorifolia*, plants with tuberous base and glabrous, strap-shaped leaves, as in Shogoin or Japanese turnip, for example; and the variety *septiceps*, seventop turnip, plants producing numerous stems from a woody taproot.

In this country turnips are grown chiefly for table use, the young tops being popular for greens. Seventop turnip is planted exclusively for greens, and the plants are often found as escapes from cultivation in southern localities.

SARSON; INDIAN COLZA

Brassica campestris var. *sarson* Prain (*45, p. 24*)

The variety sarson includes in part *Brassica glauca* Wittm., *B. quadrivalvis* H. f. et Thoms., and *B. trilocularis* H. f. et Thoms. (*45, p. 24–31*; *51, p. 323*). It is reported by Mohammed and Khan (*35*) to be one of the most important annual oilseed crops in certain Provinces of India. The plant is little known here, but the seed is occasionally imported for crushing.

Mohammed and Sikka (*34, 36*) state that there is a yellow-seeded and a brown-seeded form. The brown form has not come to the writer's attention, seeds of importations thus far received being pale yellow with a slight admixture of light-brown seeds that are identical in character with the yellow seeds except in color. Prain (*45*) points out that seed color cannot be used as a basis for subdividing the variety, as he had observed yellow and brown seeds occurring on the same plant, a situation similar to that in *B. hirta* (*B. alba*). Sabnis and Phatak (*47*) subdivide sarson on the habit of fruit as well as the number of valves in the pod. Prain recognizes two races, erect and pendent-fruited, but states that while distinct 2-, 3-, and 4-valved pods are to be found, he had observed intergrading forms of pod in both races, so that a clear-cut separation could not be made on that basis.

ORIENTAL VEGETABLE MUSTARDS

Three kinds of oriental or Chinese mustards are grown rather extensively for greens in this country: Petsai, or Chinese cabbage (*Brassica pekinensis* (Lour.) Rupr.) (*5, p. 97*), with several horticultural varieties; Pakchoi, or white celery mustard (*B. chinensis* L.) (*5, p. 99*); and spinach mustard, also known as Tendergreen (*B. perviridis* Bailey) (*7, p. 328*). Many of these varieties are described and illustrated by Kraus (*26*) and need not be discussed here. As will be shown, the seeds of the three kinds are very similar; a growing test is often necessary for positive determination. The plants are readily distinguishable in early seedling stages of growth.

BLACK MUSTARD

Brassica nigra (L.) Koch (*5, p. 103*)
Sinapis nigra L. (*29, p. 668*)

Seed of black mustard, also known as Trieste mustard, is used chiefly in the preparation of table mustard and for planting as a cover crop. Domestic seed production centers principally in California and the Pacific Northwest. The plants are characterized by a branching inflorescence with short, four-angled siliques appressed to the rachis.

WHITE MUSTARD

Brassica hirta Moench (*57, p. 306*)
Brassica alba (L.) Rabenh. (*5, p. 106*)
Sinapis alba L. (*29, p. 668*)

White mustard is grown in the same general localities as black mustard. The seed is utilized for table mustard, oil, and for planting as a cover crop in the western part of this country. The plants have characteristic hairy, pinnately divided leaves; siliques hairy, with long knifelike beaks, not appressed to the rachis.

BROWN, OR INDIA, MUSTARD

Brassica juncea (L.) Cosson (*5, p. 91*)
Sinapis juncea L. (*29, p. 668*)

Seed of domestic brown, or India, mustard is obtained chiefly as a byproduct from grain. It is reported to be inferior in quality to the black and white mustards in the manufacture of table mustard or for cover-crop purposes. Much of the crop is planted for table use as greens. In addition to the common field species there are a number of horticultural varieties on the market under such names as Giant Southern Curled and Ostrich Plume mustard, for example. These are commonly referred to as leaf mustards. Plants of brown mustard are distinguished from black mustard by the ascending, not appressed, fruits; siliques long and narrow, somewhat flattened, and having a corrugated appearance when mature.

A yellow-seeded form of *Brassica juncea*, of Chinese origin, is in cultivation in Montana and possibly elsewhere in the Northwest, under the name of Oriental, or McCormick, mustard. The seeds of this variety are readily distinguished from the yellow-seeded sarson, which is an entirely different plant.

Importations of brown mustard originate chiefly in central and eastern Europe and India. To the writer's knowledge, seed of Indian origin has never been used for planting in this country. The seed from European and Indian sources is quite distinct, but for practical purposes both types are classed as *B. juncea* here. Prain (*45*) has shown that the plants are distinct and refers the Indian form to *B. juncea* (L.) Hook. f. et Thoms.[9] (native name Asl-Rai) and the European form to *B. besseriana* Andrz., the Sarepta mustard of Russia. Kinzel (*25*) has pointed out the difference in histological structure of the seed coats of the two forms. The *B. besseriana* of Kinzel is in agreement with histological studies of Winton and Moeller (*58*) and Pieters and Charles (*43*). It would appear, therefore, that the seed of European origin and that cultivated in this country is *B. besseriana* and not *B. juncea*. Further investigation of this group is needed.

CHARLOCK

Brassica kaber (DC.) Wheeler (*57, p. 306*)
Brassica arvensis (L.) Rabenh. (*5, p. 104*)
Sinapis arvensis L. (*29, p. 668*)

Charlock is not a cultivated crop in this country. It is a widely distributed weed of fields and waste places, and because of its persistence in the soil it is designated as a noxious weed in certain State seed laws. The seed is sometimes obtained in quantity as a byproduct from grain, and it is reported to be planted to some extent as a cover crop in orchards on the Pacific coast where close cultivation is practiced. The fruits of charlock are borne on stout pedicels, usually ascending or somewhat spreading, sometimes almost appressed to the rachis. The silique may be glabrous or hispid, cylindrical or constricted between the seeds, with a long flat beak containing a single seed.

DISTINGUISHING THE SPECIES BY THEIR SEED

In order to distinguish the species it is necessary to study the seeds under magnification until the structural characters are recognized and assume differentiating value. The histology of the seed coats, as shown by Winton and Moeller (*58*), will be found helpful in understanding the surface features of these seeds. With experience it is possible in most cases to identify the species from a small sample of mature seed, such as a few seeds shelled from a pod. While it is not possible in all cases to identify an individual seed with certainty, it is usually possible to make a fairly reliable separation of a mixture of species. The strains or varieties of a species are not always distinguishable by their seed, and a seedling test may be necessary to make this determination. As will be shown, this is particularly true of certain varieties of the coles and mustards.

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[9] Prain's author citation apparently was made without knowledge of Cosson's earlier combination.

The magnification to be used for the study of these seeds will depend to some extent on individual preference, but it should be sufficiently high to show the necessary details clearly. It is often helpful to examine the seed first under low magnification for gross characters, then to use the higher magnification for finer distinctions. The seed descriptions that follow are based on observations made under a binocular microscope at a magnification of 40. The illustrations show the seeds magnified 8 times and 1⅕ times (see figs. 10 and 11). The greatly enlarged surface detail is not drawn to scale, but a relative proportion has been maintained throughout the series. This detail shows the character of the stippling in relation to the reticulations, as most commonly found in the species represented. The detail at the lower left in certain figures shows the character of the interspaces, as relative depth and shape, in those varieties where this is an important diagnostic feature.

Structural Features

Seeds of *Brassica* may be broadly oblong, spherical, or slightly flattened laterally. In many of the species the uneven length of the underlying palisade cells produces on the surface a network of lines or ridges of irregular pattern, the relative size of the interspaces often being characteristic of the kind. The lumina of the palisade cells appear as microscopic pits over the entire seed surface. The pits are visible at a magnification of about 40. In certain species particles of a whitish or yellowish epidermal membrane persist in these pits, so that in reflected light they appear as glistening white stipples. On one side of the seed is a depression with a distinct longitudinal ridge in the middle. This ridge indicates the position of the radicle of the embryo, lying between the edges of the conduplicate cotyledons. The hilum, or seed scar, appears as a more or less indefinite spot on the surface near the tip of the radicle. A short raised line near one end of the scar indicates the position of the chalaza. These characteristic structural features are shown in figure 6.

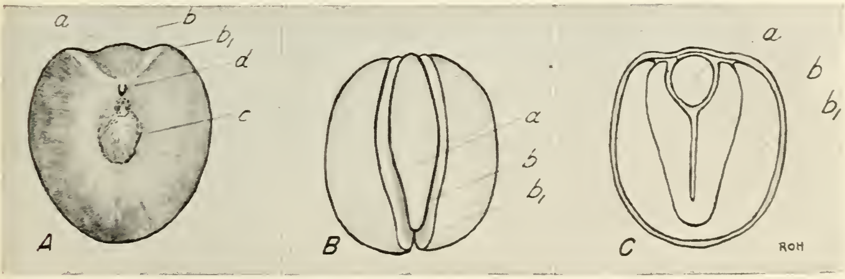

Figure 6.—Structural features of a seed of Brassica. *A*, Enlarged seed, showing tip of the radicle (*a*); edges of conduplicate cotyledons (*b*, b_1); seed scar (*c*); chalaza (*d*). *B*, Seed coat removed, showing the radicle (*a*) lying between the edges of the folded cotyledons (*b*, b_1). *C*, Cross section of seed, showing the longitudinally folded cotyledons (*b*, b_1) partially including the radicle (*a*).

The scar does not appear to have any reliable diagnostic value. It may be more or less obscure or vary in character in seeds from the same sample or in different lots of the same species. For purposes of illustration seeds were selected that show the scar detail clearly, but as a rule it is not so well defined in all seeds of a sample. The chalaza and, except as noted, the depression on the side of the seed and the grooves on either side of the radicle ridge are also too variable to be considered distinguishing features.

COLOR

Seeds in a bulk sample will appear either light-colored (pale straw or yellow) or dark (grayish black through various shades of reddish brown). Seeds of the light-colored kinds are usually uniform in color, with an occasional yellowish-brown seed present. The dark-colored kinds may have seed that is uniform in color or a mixture of shades, the entire bulk sometimes having a reddish aspect. In making a determination color is helpful to some degree, but, except in the light-seeded kinds, it may be too variable to be conclusive. As evident from the key (p. 26) the kinds having light-colored seeds now in commercial use are readily distinguished, hence attention must be directed mainly to the dark-seeded kinds.

SIZE AND SHAPE

When making a determination of seed the first consideration is size. The size of individual seeds in a sample may vary considerably, so that measurements alone are not a reliable criterion in determining a species. The relative sizes of seeds of the various kinds as they appear in bulk are shown in figures 7, 8, and 9.

Each vial contains 500 seeds taken indiscriminately from a bulk that may be considered representative of the kind under consideration. From these figures it is evident that when viewed in quantity, such as seeds shelled from a few pods, the seed will appear either relatively large (2 to 3 mm. in diameter) or small (less than 2 mm.). This places the seed in one of two possible categories, rape-cabbage or mustard. (See table 1, p. 6, for species in these groups.) As will be shown, some exceptions may be found in certain cultivated forms of the small-seeded mustards. For example, seeds of some lots of *Brassica campestris* of European origin, *B. juncea* of Indian origin, and some kinds of garden turnip average larger than 2 mm. in diameter.

Individual seeds in a sample may vary in shape, especially when immature or poorly developed, but in well-developed lots the predominant shape is often characteristic of the species. To illustrate, seeds of winter rape and charlock are spherical and roll readily on a level surface, black mustard is usually oblong, and most kinds of cabbage are flattened and variously warped. Thus, when considered in relation to other features the shape of the seed may be helpful in making a diagnosis.

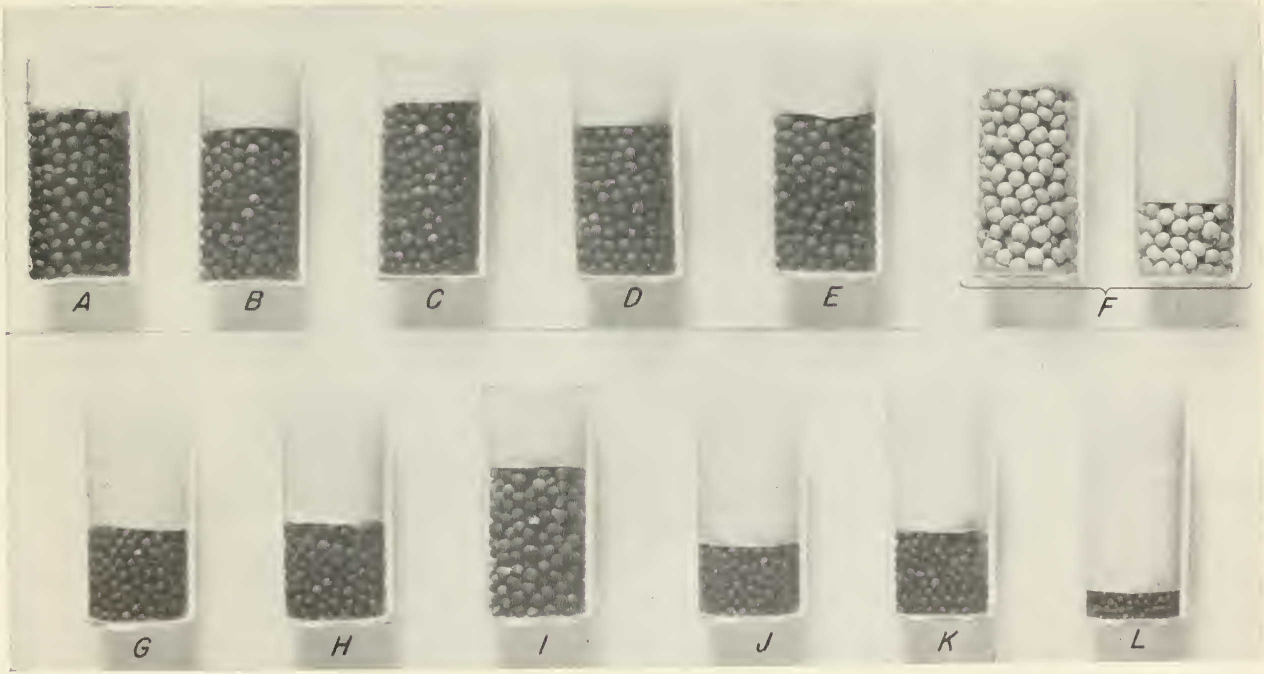

FIGURE 7.—Vials containing 500 seeds each to show the comparative size of seed of different kinds of *Brassica: A*, Winter rape; *B*, summer rape; *C*, rutabaga; *D*, Siberian kale; *E*, cabbage; *F*, white mustard; *G*, biennial turnip-rape; *H*, common turnip; *I*, Shogoin turnip; *J*, seventop turnip; *K*, charlock; *L*, wild turnip (*B. tournefortii*). (Natural size.)

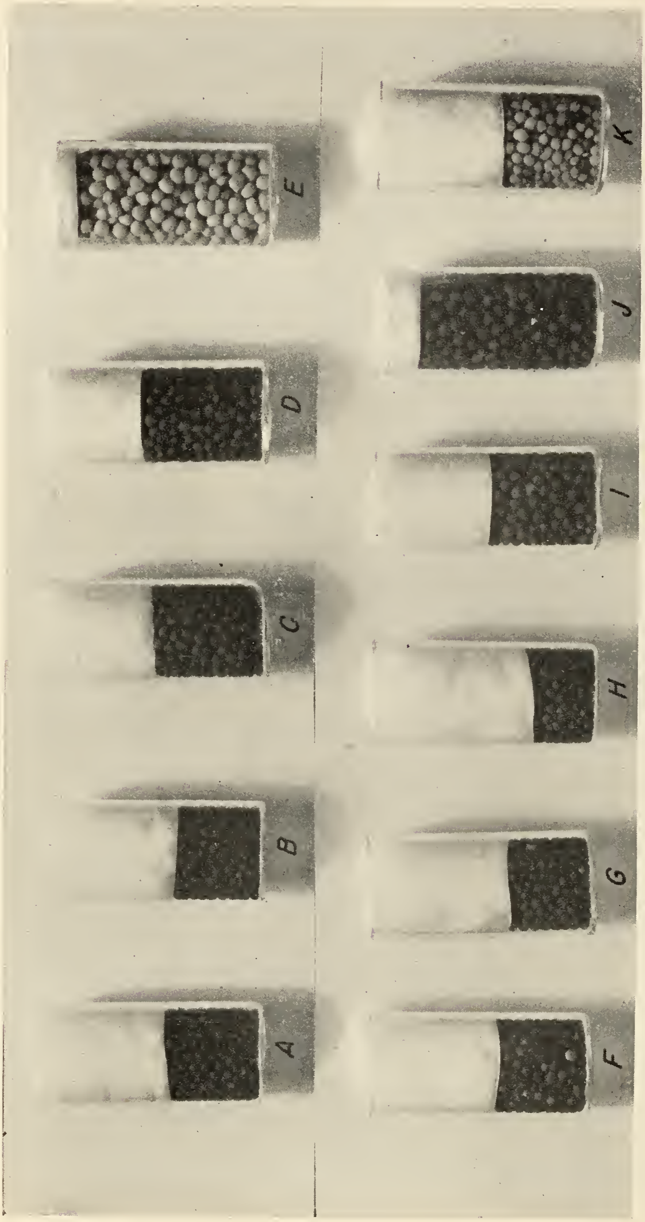

FIGURE 8.—Vials containing 500 seeds each to show the comparative size of seed of different kinds of *Brassica*: *A*, Wild turnip, West coast form; *B*, annual turnip-rape, Argentina; *C*, annual turnip-rape, central Europe; *D*, annual turnip-rape, India; *E*, sarson; *F*, black mustard; *G*, brown, or India, mustard, Montana; *H*, leaf mustard, Southern Giant Curled; *I*, brown, or India, mustard, India; *J*, brown, or India, mustard, India; *K*, oriental mustard, China. (Natural size.)

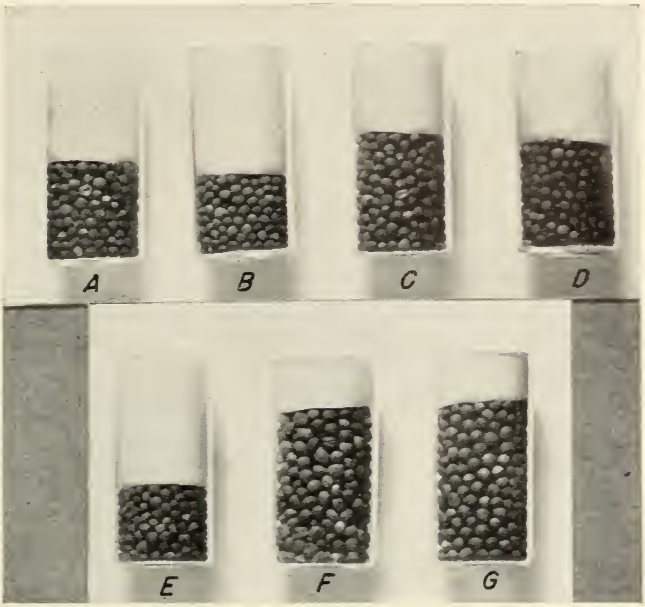

FIGURE 9.—Vials containing 500 seeds each to show the comparative size of seed of different kinds of *Brassica: A*, Spinach mustard; *B*, Pakchoi; *C*, Petsai; *D*, Scotch kale; *E*, Green Curled kale; *F*, thousand-headed kale; *G*, Chinese kale. (Natural size.)

SURFACE CONFIGURATION

The type of reticulation, the relative size of interspaces, and the character of the stippling may be considered the most important features in making a diagnosis. Because of the minute size of these structures and the possible degree of variation on a seed surface, it is not practicable to designate measurements or shapes that could be considered characteristic of a species. These features, of necessity, can be described only in relative terms, and until sufficient experience has been gained to differentiate between them it is necessary to make a comparative study of authentic seed samples of the different species.

The type of reticulation in many cases gives a reliable clue to the species. Under magnification it may appear as a network of flat whitish lines, as in winter rape; smooth cordlike lines, as in brown mustard; coarse ridges, as in rutabaga; or the reticulation may be quite obscure, as in sarson and some seeds of charlock.

The interspaces usually vary in size and shape on different parts of a seed surface. They are usually most uniform in the area along the middle, becoming longer and narrower toward the two ends. The descriptions that follow will refer to the interspaces as they most frequently appear along the median part of the seed. Seeds having pronounced ridges will have considerable depth within the interspaces, and the interspaces may be characteristically cupped or concave, as in black mustard, or flat on the bottom, as in brown mustard. The relative width and depth of interspaces is fairly characteristic in different species.

Stipples on the seed surface may be recognized as relatively large or small in proportion to the size of the seed under consideration. They are predominantly polygonal in shape, but occasionally rounded, as in winter rape. The relative size and character of the stipples (i. e., shiny or dull) are important diagnostic features.

KEY TO THE SPECIES [10]

a. Seeds pale straw color or yellow.	
b. Seeds small (less than 2 mm.); stipples distinct.	
c. Reticulations fine distinct lines (fig. 10, *K*)	23. *B. juncea.*
cc. Reticulations lacking or only faint lines (fig. 11, *H*)	14. *B. campestris* var. *sarson.*
bb. Seeds large (2 mm. or more); stipples not evident; reticulations thick and indefinite or obscured; interspaces very small (fig. 10, *F*)	6. *B. hirta.*
aa. Seeds grayish black, dull brown, or reddish.	
b. Seeds large (2 to 3 mm.).	
c. Stipples small, dull or shiny; interspaces small, shallow, poorly defined (except in 5).	
d. Reticulations thin and flat (fig. 10, *A*)	1. *B. napus* var. *biennis.*
dd. Reticulations thicker than (1), not sharply defined; stipples on ridges plainly evident (fig. 10, *B*)	2. *B. napus* var. *annua.*
(Fig. 10, *D*)	3. *B. napus* var. *pabularia.*
ddd. Reticulations narrow, well-defined lines; stipples minute (fig. 10. *E*)	5. *B. oleracea.*
cc. Stipples large, shiny; interspaces large, shallow, poorly defined; reticulations broad and thick, not sharply defined (fig. 10, *C*)	4. *B. napus* var. *napobrassica.*
bb. Seeds small (less than 2 mm.). Some exceptions in 9, 12, 18, 21.	
c. Stipples minute, partially obscured.	
d. Reticulations fine, poorly defined, or obscure; interspaces very small (fig. 10, *L*)	15. *B. kaber.*
dd. Reticulations prominent silvery lines; interspaces small (fig. 11, *I*)	16. *B. tournefortii.*
ddd. Reticulations distinct, thick raised lines; interspaces large, concave, glossy (fig. 10, *G*)	24. *B. nigra.*
cc. Stipples larger, distinct, dull or shiny.	
d. Reticulations distinct fine lines devoid of stipples.	
e. Interspaces large, shallow, not concave (fig. 10, *H*)	20. *B. juncea.*
ee. Interspaces smaller, deeper, mostly concave (fig. 10, *I*)	21. *B. juncea.*
(Fig. 10, *J*)	22. *B. juncea.*
dd. Reticulations fine ridges with stipples evident; interspaces very small but well defined, with shiny, prominent stipples (fig. 11, *A–G*)	7–13. *B. campestris.*
ddd. Reticulations reduced or lacking; interspaces very small (larger in 18), poorly defined, in occasional seeds larger and distinct (fig. 11, *J*)	17. *B. perviridis.*
(Fig. 11, *K*)	18. *B. pekinensis.*
(Fig. 11, *L*)	19. *B. chinensis.*

DESCRIPTIONS OF SEEDS [11]

1. *Brassica napus* var. *biennis* (Schubl. and Mart.) Reichb., winter rape (Swede rape) (fig. 10, *A*).—Color uniformly grayish black or with a varying proportion of the bulk red to reddish brown, smooth and clean-cut in appearance; seeds 2 to 3 mm. in diameter, spherical in well-developed lots; reticulations thin and flat, sometimes indistinct, the general effect being of flat whitish lines superimposed on the

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[10] Definition of terms used in key: *Stipples*, microscopic pits on the seed surface; *reticulation*, network of lines or minute ridges; *interspace*, area bounded by the lines or ridges. (See p. 21, Structural features.)

[11] See table 2 for sources of material in figs. 10 and 11.

TABLE 2.—*Sources of material*[1] *from which drawings were made for figures 10 and 11*

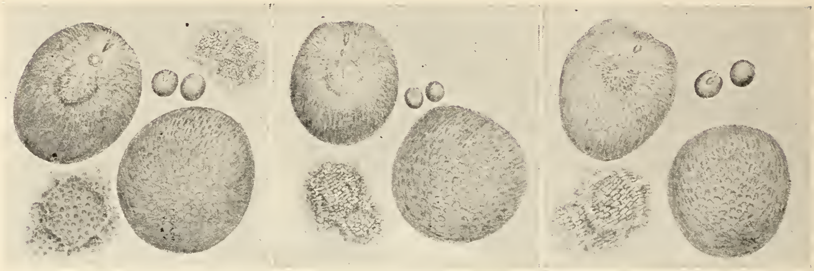
Figure reference	Species or variety of *Brassica*	Seed Investigations No.	Specimen No.	Origin
10, *A*	*B. napus*:			
	var. *biennis*	29280	R-51	Holland.
B	var. *annua*	749449	R-44	France.
C	var. *napobrassica*	222488	R-118	Holland.
D	var. *pabularia*	222489	R-119	Do.
E	*B. oleracea* var. *capitata*	222181	R-117	Do.
F	*B. hirta*	749625	R-48	Montana.
G	*B. nigra*	755616	R-111	California.
H	*B. juncea*	398841	R-115	Montana.
I	do	754538	R-75	India.
J	do	750303	R-45	Holland.
K	do	750272	R-42	China.
L	*B. kaber*	217722	R-46	Hungary.
11, *A*	*B. campestris*	755918	R-114	California.
B	do	219698	R-71	Argentina.
C	do	754539	R-73	India.
D	*B. campestris*:			
	var. *autumnalis*	218229	R-62	Germany.
E	var. *rapa*	4210	R-61	
F	do	750129	----------	Japan.
G	do	750103	----------	Domestic.
H	var. *sarson*	218476	R-39	China.
I	*B. tournefortii*	----------	R-200	California.
J	*B. perviridis*	217758	R-53	Japan.
K	*B. pekinensis*	750135	R-63	Do.
L	*B. chinensis*	222938	----------	Do.

[1] Plant specimens grown from these seeds at Arlington Experiment Farm, Arlington, Va., have been deposited in the Herbarium of the United States National Arboretum, Plant Industry Station, Beltsville, Md.

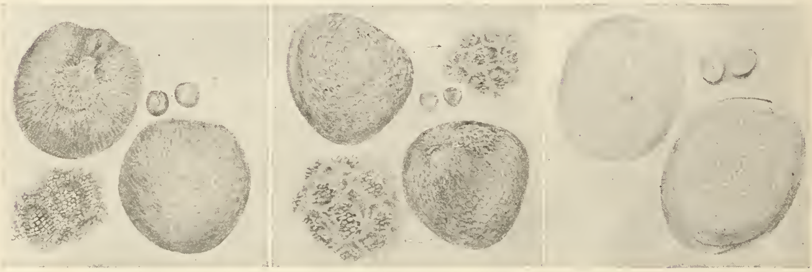
surface rather than a definite part of the seed coat; interspaces shallow and small in proportion to size of seed; stipples small, mostly wide-spaced, roundish, dull, sometimes angular and shiny. Chief distinguishing features: Large size (fig. 7, *A*), smooth surface, flat reticulations, and small, mostly dull, roundish stipples.

2. *Brassica napus* var. *annua* Koch, summer rape (fig. 10, *B*).—Color and size (fig. 7, *B*) as in (1), but not so uniformly spherical and lacking the smooth, clean-cut appearance; reticulations thicker than in (1), but not sharply defined; interspaces small in proportion to size of seed, deeper than in (1); stipples small, shiny, tend to be rectangular, sometimes roundish and dull as in (1). Chief distinctions from winter rape: Rougher surface, thicker reticulations, deeper interspaces, and angular shiny stipples.

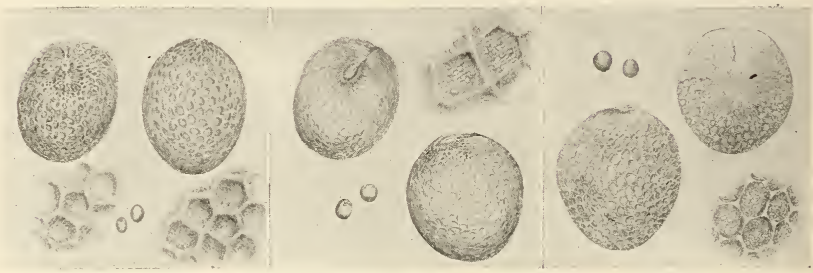
3. *Brassica napus* var. *pabularia* (DC.) Reichb., Siberian kale (fig. 10, *D*).—Color and size (fig. 7, *D*) as in (1); spherical or slightly flattened laterally; reticulations, interspaces, stipples as in (2), sometimes as in (1). The seeds may have the smooth appearance of (1) or the slightly rougher surface of (2). Poorly developed lots may have a variable proportion of small seed (less than 2 mm.). Not always distinguishable from (1) and (2).



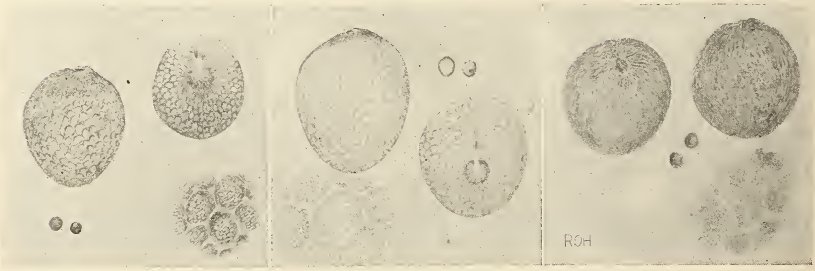
A. Winter rape, *B. napus* var. *biennis.* *B.* Summer rape, *B. napus* var. *annua.* *C.* Rutabaga, *B. napus* var. *napobrassica.*



D. Siberian kale, *B. napus* var. *pabularia.* *E.* Cabbage, *B. oleracea* var. *capitata.* *F.* White mustard, *B. hirta* (*B. alba*).

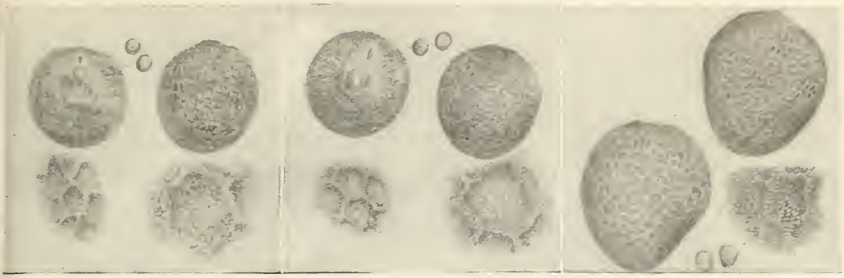


G. Black mustard, *B. nigra.* *H.* Brown mustard (domestic), *B. juncea.* *I.* Brown mustard (India), *B. juncea.*



J. Brown mustard var. giant curled, *B. juncea.* *K.* Oriental mustard, *B. juncea.* *L.* Charlock, *B. kaber* (*B. arvensis*).

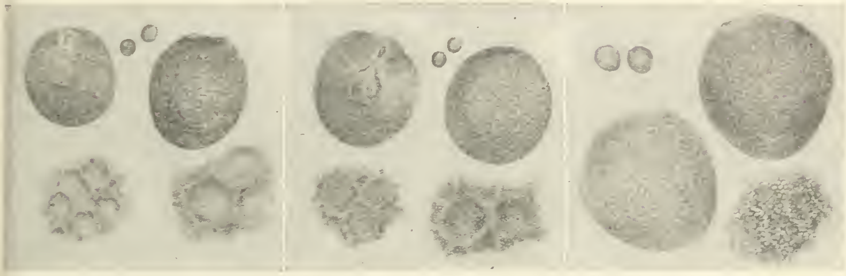
FIGURE 10.—Seeds of *Brassica* (8 and 1⅕ times natural size); enlarged surface detail not drawn to scale (see p. 21).



A. Wild turnip (Pacific coast), *B. campestris.*

B. Annual turnip-rape (Argentina), *B. campestris.*

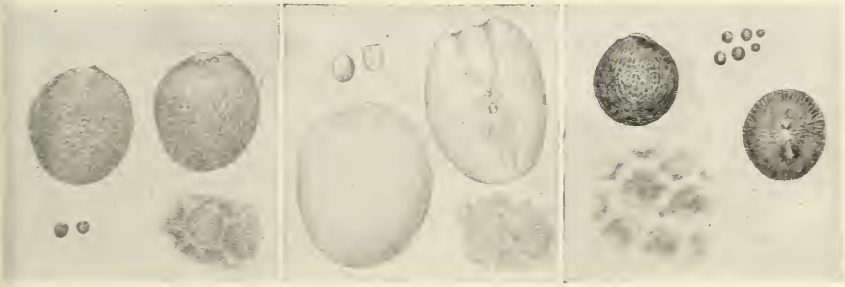
C. Annual turnip-rape (India), *B. campestris.*



D. Biennial turnip-rape, *B. campestris* var. *autumnalis.*

E. Turnip, common, *B. campestris* var. *rapa.*

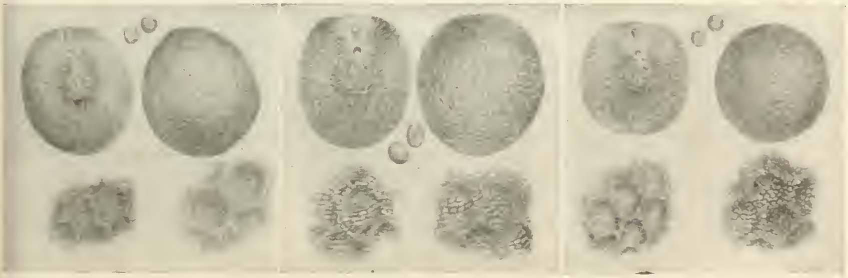
F. Turnip, Shogoin, *B. campestris* var. *rapa.*



G. Turnip, seventop, *B. campestris* var. *rapa.*

H. Sarson, *B. campestris* var. sarson.

I. Wild turnip, *B. tournefortii.*



J. Spinach mustard, *B. perviridis.*

K. Petsai, or Chinese cabbage, *B. pekinensis.*

L. Pakchoi, or celery cabbage, *B. chinensis.*

FIGURE 11.—Seeds of *Brassica* (8 and 1⅕ times natural size); enlarged surface detail not drawn to scale (see p. 21).

4. *Brassica napus* var. *napobrassica* (L.) Reichb., rutabaga (Swede turnip) (fig. 10, *C*).—Color grayish black, often with adhering patches of bronze-colored epidermal tissue; surface less smooth than (1); seeds 2 to 3 mm. in diameter, many seeds flattened laterally or angular in outline; reticulations broad and thick but not sharply defined, stipples clearly evident on the ridges; interspaces large; stipples large, tend to be rectangular in shape, shiny, occasionally roundish and dull as in (1). Chief distinctions: Large size (fig. 7, *C*), roughened surface, broad and thick reticulations, mostly with large interspaces, and large, shiny, rectangular stipples.

5. *Brassica oleracea* var. *capitata* L., cabbage (fig. 10, *E*).—Grayish brown to bronze-colored, grayish black or reddish, with a grayish translucent epidermal tissue persisting in spots, seeds 2 to 3 mm. in diameter, variously compressed, often triangular in outline, or somewhat spherical in certain varieties; reticulations narrow, well-defined lines usually devoid of stipples, the fine lines having a waxy, semipolished appearance; interspaces small, well defined; stipples minute, dull or shiny; both reticulations and stipples may be partially obscured by the persisting epidermal tissue so that the surface often appears waxy and rugose. Chief distinguishing features: Large size (fig. 7, *E*), small interspaces, and partially obscured fine reticulations and minute stipples.

The species includes numerous botanical and horticultural varieties other than cabbage (see table 1, p. 6). The seeds of all the varieties exhibit the specific features of *B. oleracea* as described for cabbage, but the varieties are not always distinguishable. Seeds of the common kitchen kales can sometimes be distinguished from other varieties of the *oleracea* group by the smaller size, smoother surface, and more distinct stipples. The comparative sizes of these seeds are shown in figure 9, *D* to *G*.

6. *Brassica hirta* Moench. (*B. alba*), white mustard (fig. 10, *F*).—Pale-straw color with a pinkish cast, occasional seed light or yellowish brown, surface rugose; seeds approximately 3 mm. in diameter (fig. 7, *F*), flattened laterally, occasionally spherical; reticulations broad and thick, partially or completely obscured by a translucent epidermal layer; interspaces very small; stipples not evident.

7. *Brassica campestris* L., wild turnip, west coast form (fig. 11, *A*).—Uniformly grayish black, or with a variable proportion of reddish or reddish-brown seeds; mostly spherical in well-matured seed, surface finely roughened; reticulations distinct, well defined; interspaces small, in occasional seeds large and reticulations coarse; stipples polygonal, shiny, distinct. Comparative size of seed is shown in figure 8, *A*.

8. *Brassica campestris* L., annual turnip-rape (bird rape), origin Argentina (fig. 11, *B*).—Similar in size (fig. 8, *B*) and character to wild turnip (7). The two forms are difficult to distinguish.

9. *Brassica campestris* L., annual turnip-rape (bird rape), origin India (fig. 11, *C*).—With the exception of No. 14, seeds of cultivated varieties received from India tend to be larger than those from European and Argentine sources (fig. 8, *B*, *C*, and *D*); mostly flattened laterally; color predominantly reddish; reticulations flat and poorly defined, sometimes lacking, so that seed appears smoother than in varieties from other sources; stipples small, mostly shiny, usually not so prominent as in turnip and turnip-rapes from other sources.

10. *Brassica campestris* var. *autumnalis* DC., biennial turnip-rape (fig. 11, *D*).—Various shades of reddish brown, not usually uniformly grayish black as in (7) and (8); surface finely roughened; reticulations distinct and well defined, in occasional seeds coarse and prominent, sometimes obscure or lacking; interspaces small, or larger in seeds with coarse reticulations; stipples polygonal, shiny, prominent; seed often has an oily or smeary appearance. For comparative size of seed, see figure 7, *G*.

11. *Brassica campestris* var. *rapa* (L.) Hartm., turnip, common (fig. 11, *E*).—Size may vary rather widely in different varieties (compare *H*, *I*, and *J* in fig. 7); color mostly reddish brown, sometimes grayish black; surface features as in biennial turnip-rape (10), but seed tends to be slightly smoother and more clear-cut. Not always distinguishable from the turnip-rapes.

12. *Brassica campestris* var. *rapa* (L.) Hartm., turnip, Shogoin or Japanese (fig. 11, *F*).—Seeds large, mostly more than 2 mm. in diameter (fig. 7, *I*); reddish, flattened; reticulations obscure so that seed appears quite smooth; interspaces smaller than in common turnip, shallow; stipples distinct and shiny as in common turnip.

13. *Brassica campestris* var. *rapa* (L.) Hartm., turnip, seventop (fig. 11, *G*).—Seeds average smallest of the edible turnips (fig. 7, *J*); color dark reddish brown; reticulations, interspaces, and stipples as in turnip-rape (10).

14. *Brassica campestris* var. *sarson* Prain, sarson, or Indian colza (fig. 11, *H*).—Pale-straw color with a pinkish cast, an occasional seed yellowish brown; slightly flattened laterally; reticulations lacking or indistinct; interspaces lacking or only faintly evident; stipples shiny, fine, distinct. Comparative size of seed is shown in figure 8, *E*.

15. *Brassica kaber* (DC.) Wheeler (*B. arvensis*), charlock (fig. 10, *L*).—Dull black or reddish; spherical, not depressed between the cotyledons; smooth and velvety under low magnification; under higher magnification (× 40) the surface appears slightly roughened by thick, flat reticulations with very small interspaces; stipples minute, mostly dull; stipples and reticulations more or less obscured by a mucilaginous epidermal layer. See figure 7, *K*, for comparative size of seed. Chief distinguishing features: Spherical shape, velvety surface, partially obscured minute stipples.

16. *Brassica tournefortii* Gouan., wild turnip (fig. 11, *I*).—The smallest of the *Brassica* species, 1 to 1½ mm. in diameter (fig. 7, *L*); dark reddish brown; quite uniformly spherical, no depression evident between the cotyledons; reticulations prominent, surface heavily coated with a mucilaginous substance so that reticulations appear as coarse silvery lines; interspaces small; stipples minute, usually completely obscured by the mucilaginous coating. When wet, the seed is quickly coated with a thick layer of transparent mucilage. The small size and prominent whitish reticulations distinguish this species from charlock (15) and certain small-seeded forms of *B. campestris*. As in charlock, a single seed is produced in the beak of the pod.

17. *Brassica perviridis* Bailey, spinach mustard, or Tendergreen (fig. 11, *J*).—Grayish black or dull reddish brown, slightly flattened laterally or spherical; size about as in common turnip (compare fig. 9, *A*, with fig. 7, *H*); surface appears smooth; reticulations rather fine and flat, sometimes lacking; interspaces very small and poorly defined, in occasional seeds larger and reticulations coarser; stipples shiny,

but not usually so prominent as in turnip. The smoother appearing surface helps to distinguish this species from turnip.

18. *Brassica pekinensis* (Lour.) Rupr., Petsai, or Chinese cabbage (fig. 11, *K*).—Differs from spinach mustard (17) in its larger size, 2 mm. or more (fig. 9, *C*), somewhat coarser reticulations, and larger interspaces. In occasional seeds reticulations may be very coarse, or lacking. Stipples tend to be rectangular in shape, shiny, and slightly larger than in (17). As in (17), the smoother surface helps to distinguish the species from turnip.

19. *Brassica chinensis* L., Pakchoi, or white celery mustard (fig. 11, *L*).—The seed is similar to spinach mustard (17) in surface character and size (fig. 9, *B*). The reticulations are usually thicker and better defined, but the two species are difficult to distinguish.

20. *Brassica juncea* (L.) Cosson, brown, or India, mustard (origin Montana) (fig. 10, *H*).—Reddish brown to dark brown; spherical or slightly flattened, surface smooth and clean-cut; reticulations appear like fine distinct lines superimposed on the surface, the lines devoid of stipples; interspaces large, shallow, usually not concave; stipples small but larger than in black mustard (24). Comparative size of seed shown in figure 8, *G*. Seed of European origin (not illustrated) appears to be identical with domestic seed. Seeds of brown, or India, mustard may be distinguished from *B. campestris* by the fine, sharply defined reticulations devoid of stipples and larger interspaces with less conspicuous stipples. Compare also with black mustard (24).

21. *Brassica juncea* (L.) Cosson, brown, or India, mustard (origin, India) (fig. 10, *I*).—Dusty grayish black to dark reddish brown, slightly flattened laterally; seeds of certain strains from this source large, more than 2 mm. in diameter (fig. 8, *J*); reticulations fine narrow ridges; interspaces mostly smaller than in domestic seed (20), deeper, concave; stipples small, shiny. Chief distinctions from domestic type (20) are the larger size of some of the strains, darker color, and reticulations that appear more like sharp ridges than lines.

22. *Brassica juncea* (L.) Cosson, leaf mustard (fig. 10, *J*).—Several horticultural varieties of this species are in cultivation, such as Southern Giant Curled, Ostrich Plume, and Fordhook Fancy. The seeds are smaller in size but have the same general character as the India type (21). Well-developed seed is usually uniform in size and surface configuration. It differs from the domestic type (20) in the more raised reticulations and smaller, mostly concave, interspaces. Comparative size of seed is shown in figure 8, *H*.

23. *Brassica juncea* (L.) Cosson, oriental field mustard (fig. 10, *K*).—Seeds light yellow, an occasional seed yellowish brown; other features as in the brown-seeded form (20). Comparative size of seed shown in figure 8, *K*.

24. *Brassica nigra* (L.) Koch, black, or Trieste, mustard (fig. 10, *G*).—Reddish to dark brown; broadly oblong or slightly flattened, sometimes smaller than brown mustard (20); reticulations thick and cordlike and devoid of stipples; interspaces smaller than in (20), concave, the surface glossed over by a mucilaginous layer so that stipples are partially or completely obscured; stipples minute. May be distinguished from brown mustard (20) by the thick raised reticulations, glossy concave interspaces, and minute stipples. Size of seed shown in figure 8, *F*.

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